Rocky Mountains Southwest Great Plains

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Effects of Highway Construction on Water Quality and Biota in an Adjacent Colorado Mountain Stream[1]

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Highway construction increased suspended solids and channel sedimentation, while nine other water quality variables were unaffected in an adjacent, high elevation stream. Epilithon standing crop and macroinvertebrate density decreased and compositional changes were noted. Effects were more pronounced in depositional areas. No change in fish condition was detected.

Keywords: Highway construction, water quality, fish habitat, sedimentation

Management Implications

In streams adjacent to highway construction, hydrological and biological changes may be prevented when adequate sediment control measures are used in conjunction with brief periods and minimal areas of construction activities. Sedimentation, which often alters the density and species composition of stream biota, may be precluded if work occurs during high streamflow periods (e.g., snowmelt runoff), or ameliorated if followed by an erosional flow (e.g., runoff or reservoir release). Future studies should include sampling of both erosional and depositional areas in streams to insure a complete evaluation of biological or hydrological alterations.

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Introduction

Colorado State Highway 14 enters the mouth of the Cache la Poudre Canyon northwest of Fort Collins in Larimer County, and proceeds westward over Cameron Pass (3,135 m) where it enters Jackson County. An unimproved road was first built between 1912 and 1926, with improvements made (realignment, widening, and paving) in subsequent years. In 1972, when approximately 20 km of dirt road remained, plans were made to improve this section to be a paved all-weather road.

The Final Environmental Impact Statement[5] cited positive environmental effects, including elimination of rock slide areas, improvement of drainage, reduction of weather-related hazards, elimination of erosion from the road surface, and reduction of air pollution (dust). Probable adverse impacts included more wildlife hit by vehicles, reduced aesthetic appearance because of the larger right-of-way and presence of asphalt, increased maintenance costs, greater natural resource damage

[5]*United States Department of Transportation, Federal Highway Administration, and Colorado Division of Highways. 1974. Final environmental statement, administrative action for project S0014(2), Cameron Pass, Jackson and Larimer Counties. FHWA-Colo-EIS-73-01-F.*

caused by increased use of the area for recreation, and damage to stream ecosystems during highway construction activities.

Because of the potential damage to stream ecosystems, a 3-year study was performed to assess the effect of construction activities on Joe Wright Creek, along the area of construction. Joe Wright Creek was thought to be especially susceptible to disturbance. Its inertia (i.e., ability to resist disturbance) and resilience (i.e., degree, manner, and pace of restoration after disturbance) were believed to be low, based upon criteria by Cairns (1976) and Westman (1978).

Study Area

Joe Wright Creek is a small tributary of the Big South Fork of the Cache la Poudre River (fig. 1). Stream elevation ranges from 3132 m to 2545 m, over a distance of 22 km. Average stream channel slope is 3% with a maximum of 5% and a minimum of 2.2%. The stream channel itself is heavily armored because of highly erosive inflows from transmountain diversions since 1904 (Flook 1974).

Eight sites (2716 m-3045 m) were sampled during the ice-free months (June-October) of 1975, 1976, and 1977. Sites sampled during any one-year were selected to coincide with the progressive upstream movement of construction activities (fig. 1). In 1975 and 1976, site pairs 5-6 and 7-8 were sampled; site pairs 1-2 and 3-4 were sampled in 1977. Site 1 also was sampled during 1975 and 1976 as a reference site to detect variations among years.

Before construction began, stream substrate was predominantly pebble and cobble[6] at sites 1-6; boulder and cobble predominated at sites 7 and 8. Riffles were more numerous than pools at sites 1 and 2, equally abundant at sites 3-6, and variable at sites 7 and 8 because of impoundment discharges. Riparian vegetation consisted of grasses and sedges, Engelmann spruce (*Picea engelmannii*), alder (*Alnus tenuifolia*), and willows (*Salix* spp.).

Highway construction activities potentially detrimental to the Joe Wright Creek ecosystem during the 3 years of study were: (1) riparian vegetation removal above sites 4 and 8 (fig. 2a); (2) channel realignment above sites 2, 4, and 8 (fig. 2b); and (3) culvert installation or bridge construction above sites 2, 4, and 6 (fig. 2c). Erosion from exposed streambanks was minimized with temporary installations of straw bales lined with plastic; however, in a few instances, appreciable sedimentation occurred downstream from areas where bales were dislodged (fig. 2d). Also, significant amounts of sediment entered the stream at crossing sites where rock and soil were backfilled (fig. 2e).

[6]*Sand: particles less than 2 mm diameter; gravel: 2-16 mm diameter; pebble: 16-64 mm diameter; cobble: 64-256 mm diameter; boulders: more than 256 mm diameter.*

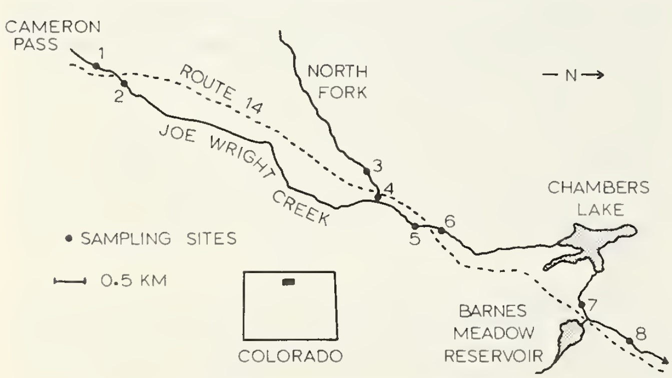

Figure 1.—Joe Wright Creek study area, 1975-1977.

Methods

A total of 47 field trips were made during the ice-free months—18 in 1975, 11 in 1976, and 18 in 1977—to collect water quality and biological samples. The earliest field trip was May 21 and the latest November 14, but most data were collected from June to mid-October.

Water quality was tested every 2 weeks. Suspended and dissolved solids measurements were made from 1-liter samples processed (organic and inorganic portions) according to procedures outlined in Standard Methods (American Public Health Association et al. 1976). Dissolved oxygen was measured in the field using the azide modification of the Winkler Method. Free and bound carbon dioxide (CO_2 and $CaCO_3$, respectively) were measured titrimetrically using phenolphthalein and methyl orange indicators. Water pH was measured in the field with Hellige[7] color disks. Water temperature was determined with a hand-held mercury thermometer having 1° C graduations.

Discharge was measured with a No. 622 Gurley Current Meter.[7] Sites with no intervening tributary were assumed to have the same discharge.

Substrate was sampled with a 28-cm diameter core. In 1975 and 1976, samples were taken, in fast water (erosional) areas only, on eight dates. In 1977, one sample each was taken in fast water and slow water (depositional) areas on three dates. After forcing the core into the substrate, all material was removed to a depth of at least 5 cm and returned to the laboratory. The substrate was dried, separated into size classes with sieves, and weighed.

Epilithon (plants and detritus on rock surfaces) was scraped from the upper surfaces of at least 10 cobble-sized rocks during a 5-minute period and preserved in 5% formalin. The dry weight of each sample was obtained after oven drying, at 60° C, for 12 hours and desiccation for 24 hours. Loss-on-ignition values were determined by ashing the samples at 650° C, for 1 hour, followed by desiccation for 24 hours before weighing.

Macroinvertebrates were sampled every 2 weeks with a 700 μm mesh Surber sampler[7] enclosing an area of 929 cm². In 1975 and 1976, six replicates were taken in fast water areas of riffles, at each site, on each sampling date. In 1977, four replicates each were taken

[7]*The use of trade and company names is for the benefit of the reader; use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

Figure 2.—Phases of highway construction, Joe Wright Creek: a) removal of riparian vegetation, b) channel re-alignment, c) culvert installation, d) erosion control with hay bales and plastic, and e) direct incursion of backfill materials at stream crossing.

in fast water and slow water areas. All samples were preserved in 5% formalin and transported to the laboratory. In the laboratory, organisms were separated from detritus and placed in 80% ethyl alcohol for identification and enumeration.

Macroinvertebrate biomass values were obtained by displacement, assuming a specific gravity of 1.0. Macroinvertebrate diversity values were computed with the Shannon-Weaver Diversity Index:

$$\bar{d} = [3.3219/N]\,(N\log_{10}N - \Sigma n_i \log_{10} n_i) \qquad [1]$$

where:

3.3219 is the conversion factor to base 2 logarithms,
N is the total number of individuals, and
n_i is the total number of individuals of i^{th} taxon.

The value for "total diversity" as used in this study was obtained using the actual number of species and organisms collected on all dates, in any one season, at each sampling location.

Fish were collected with a backpack electrofishing unit. Weight, length, and scales were taken before releasing each fish collected. Selected fish were killed to remove and analyze their sagittae and stomach contents.

For age determinations, scales were soaked in 0.1 M NaOH solution for approximately 5 minutes, were mounted between glass slides, and later were examined under a binocular dissecting microscope. The scales were magnified to 80× using a scale projector and examined using criteria outlined by Tesch (1971).

Otoliths were stained with Alizarin Red S in an excess of NH_4OH to enhance annulus recognition. Annuli were counted using a binocular dissecting microscope and transmitted light.

Fish stomach contents were placed in a petri dish for separation into major taxa and were further separated to lower taxa, when possible. Volume determinations of each major taxon were determined by displacement. Frequency of occurrence and percentage by number and volume were determined for each taxon.

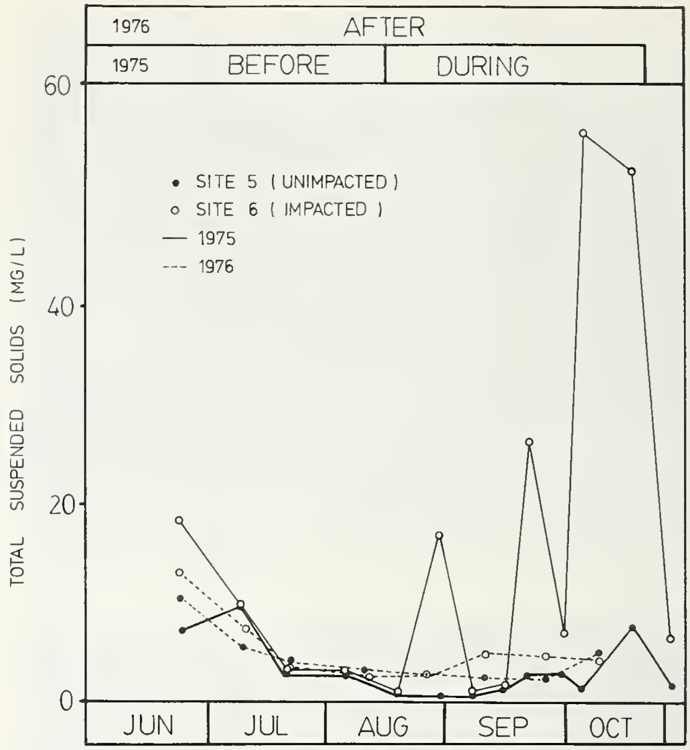

Figure 3.—Suspended solids levels above (site 5) and below (site 6) bridge foundation excavation, 1975-1976.

Results and Discussion

Physicochemical Parameters

Water chemistry parameters not significantly affected by construction activities were: total dissolved solids, organic fraction of dissolved solids, organic fraction of suspended solids, pH, free and bound carbon dioxide, and dissolved oxygen (90-120% saturation) (table 1). Apparent significant changes in stream discharge and water temperature were a function of increasing stream order and time of sampling, respectively.

In this study, most water quality variables were not significantly affected by highway construction activities, a conclusion also reached by Barton (1977), Extence (1978), and Porter et al. (1974). The changes in dissolved oxygen and biological oxygen demand (BOD) found by Porter et al. (1974) and Extence (1978) did not happen in Joe Wright Creek because of its high flushing rate and low organic load.

In contrast, suspended solids levels usually increased significantly below construction areas (table 1). In 1975, when a bridge foundation was excavated above site 6, suspended solids levels at this site increased as much as 40 times (fig. 3). However, these increases were short-lived because the construction activities were relatively short-lived and the flushing rate of the stream was high. Furthermore, in 1976, after bridge construction had been completed above site 6, suspended solids levels were comparable to those of site 5, indicating that recovery was complete and may have been aided by further flushing during spring runoff (fig. 3). Similar increases followed by rapid decreases occurred at sites 2 and 4, where there was channel realignment and culvert installation in 1977. No significant change in suspended solids levels was detected at site 8 because of dilution by releases from Barnes Meadow Reservoir.

Elevated suspended solids levels can lead to changes in stream morphology via sedimentation (Leedy 1975, U.S. Department of Transportation and Federal Highway Administration 1975). In this study, substrates below construction areas accumulated fine particles; the effect was more pronounced in slow water areas. When construction took place during snowmelt runoff or below a discharging reservoir (site 8), sedimentation was minimal. Snowmelt runoff in the season following highway construction served to flush most accumulated sediment farther downstream.

In 1977, the roles of discharge and current were further elucidated by partitioning substrate samples between slow and fast water areas. Slow water substrate areas accumulated gravel and sand particles, except during spring runoff discharges. Construction activities during other times resulted in sand and gravel accumulation; although some recovery was noted, it varied by site. Fast water areas did not accumulate gravel and sand during construction activities but did accumulate such particles over a longer period of time, during periods of low discharge.

Epilithon

Response of mean standing crop of epilithon to construction activities was mixed (table 2). However, loss-on-ignition values, which more accurately portray the

Table 1.—Physical and chemical variables (mean values), Joe Wright Creek, 1975-1977

	Study site							
Variable	1(U)[1]	2(A)	3(U)	4(A)	5(U)	6(A)	7(U)	8(A)
Discharge (m^3/min)								
1975	17.4	-	-	-	17.4	17.4	120.0	143.0
1976	19.2	-	-	-	15.6	15.6	168.0	168.0
1977	10.2	14.4	12.6	12.6	-	-	-	-
Total suspended solids (mg/l)								
1975	1.3	-	-	-	3.2	15.8	10.9	7.7
1976	2.1	-	-	-	4.3	5.5	8.0	9.1
1977	16.7	75.1	3.4	80.7	-	-	-	-
Total dissolved solids (mg/l)								
1975	33.4	-	-	-	34.7	35.3	30.9	34.4
1976	16.5	-	-	-	19.3	26.4	42.6	29.4
1977	33.2	30.6	25.4	30.5	-	-	-	-
pH (mode)								
1975	7.2	-	-	-	7.2	7.2	7.2	7.2
1976	7.1	-	-	-	7.2	7.2	7.2	7.3
1977	7.3	7.2	7.2	7.2	-	-	-	-
Free carbon dioxide (mg/l)								
1975	1.4	-	-	-	1.4	1.3	1.5	1.0
1976	1.4	-	-	-	1.6	1.5	1.8	1.7
Bound carbon dioxide (mg/l)								
1975	13.0	-	-	-	12.0	12.1	9.7	10.8
1976	10.2	-	-	-	11.3	11.1	9.2	10.0
1977	10.8	9.9	11.8	11.6	-	-	-	-
Dissolved oxygen (mg/l)								
1975	9.5	-	-	-	9.6	9.3	8.6	8.6
1976	9.2	-	-	-	9.0	8.9	8.2	8.2
1977	11.8	11.1	10.3	10.1	-	-	-	-
Temperature (°C)								
1975	1.4	-	-	-	2.1	3.5	7.5	7.6
1976	2.5	-	-	-	3.4	4.8	8.3	8.4
1977	3.7	4.9	7.1	7.8	-	-	-	-
Suspended solids organic portion - mg/l (percentage of total)								
1975	0.2	-	-	-	0.4	1.1	1.2	1.0
	(1)	-	-	-	(13)	(14)	(13)	(14)
1976	0.4	-	-	-	1.9	2.7	3.2	2.8
	(26)	-	-	-	(22)	(23)	(36)	(29)
1977	2.1	11.6	0.9	13.3	-	-	-	-
	(19)	(15)	(36)	(30)	-	-	-	-
Dissolved solids organic portion - mg/l (percentage of total)								
1975	11.6	-	-	-	11.4	11.5	11.3	13.7
	(35)	-	-	-	(33)	(33)	(37)	(40)
1976	5.1	-	-	-	6.0	7.5	8.6	10.0
	(29)	-	-	-	(29)	(31)	(26)	(40)
1977	11.2	10.3	9.9	10.2	-	-	-	-
	(38)	(37)	(42)	(37)	-	-	-	-

[1] *U = unaffected site, A = affected site*

organic fraction, were consistently lower at affected sites. The sharply higher values of both mean standing crop and loss-on-ignition values at site 7 may be attributable to the relatively constant flow conditions and high incident solar radiation below Chambers Lake (Ward 1974, 1976).

The major components of epilithon (algae, detritus, moss, and lichen) varied according to date and site. There tended to be a lower percentage of algae and higher percentage of detritus at construction affected sites; lichen and moss occurred only infrequently.

Species composition of the epilithon varied greatly according to site and date. A total of 110 taxa were collected. *Hydrurus foetidus* (Chrysophyta) was the most abundant taxon early in the year, because it was favored by the cold temperature and relatively constant

Table 2.—Mean standing crop (mg per 5 minutes of scraping) and loss-on-ignition (LOI) of epilithon, Joe Wright Creek, 1975-1977

	Study site							
Year	1(U)[1]	2(A)	3(U)	4(A)	5(U)	6(A)	7(U)	8(A)
Dry weight (mg/5 min scraping)								
1975	25.3	-	-	-	44.0	65.4	255.1	34.4
1976	26.2	-	-	-	69.7	53.6	248.8	78.6
1977	12.6	10.8	29.6	26.0	-	-	-	-
Loss-on-ignition (mg/5 min scraping)								
1975	7.0	-	-	-	9.3	8.1	13.5	7.3
1976	1.9	-	-	-	18.3	9.4	53.2	14.8
1977	5.0	3.7	7.7	7.0	-	-	-	-

[1]U = unaffected site, A = affected site

Table 3.—Macroinvertebrate variables, Joe Wright Creek, 1975-1977

	Study site							
Variable	1(U)[1]	2(A)	3(U)	4(A)	5(U)	6(A)	7(U)	8(A)
Average total density (org./m^2)								
1975F[2]	1471.3	-	-	-	930.9	963.6	1256.3	1258.1
1976F	776.4	-	-	-	826.5	623.0	308.3	599.3
1977F	697.4	346.3	701.6	402.0	-	-	-	-
1977S	559.7	147.1	530.5	296.9	-	-	-	-
Average total biomass (g/m^2 wet weight)								
1975F	3.9	-	-	-	4.1	5.2	2.5	3.4
1976F	2.7	-	-	-	2.4	2.7	1.0	1.5
1977F	4.3	1.1	2.7	1.5	-	-	-	-
1977S	3.9	0.7	1.6	0.9	-	-	-	-
Total diversity[3]								
1975F	4.3	-	-	-	3.7	4.1	3.1	3.5
1976F	3.8	-	-	-	4.1	4.0	3.6	2.5
1977F	3.8	3.4	3.3	3.3	-	-	-	-
1977S	3.8	3.7	3.9	3.6	-	-	-	-
Total number of taxa								
1975F	69	-	-	-	67	67	50	58
1976F	41	-	-	-	44	46	27	27
1977F	41	41	43	41	-	-	-	-
1977S	37	41	49	44	-	-	-	-

[1]U = unaffected site, A = affected site
[2]F = fast water sample, S = slow water sample
[3]Shannon Weaver Index; value computed using actual total number collected per taxon, for entire sampling season.

discharge during ice-over. After snowmelt runoff, one of the following divisions and taxa tended to predominate: Cyanophyta (esp. *Rivularia* sp.), Bacillariophyta (esp. *Gomphonema* spp., *Achnanthes* spp., or *Synedra* spp.), or Rhodophyta (*Lemanea violaceae*, *Audouinella fucina*).

In summary, epilithon dry weight (organic fraction) and species richness were slightly reduced below three of four construction areas; however, no comment on the response of specific taxa may be made because of the limited sampling regime.

Macroinvertebrates

In 1975 and 1976, no detectable difference was found in overall macroinvertebrate density or biomass (table 3) between unaffected and affected sites. Exemplary data from sites 5 and 6 indicate that, even during construction in 1975, when suspended solids and substrate fine particles increased dramatically, there was no detectable reduction of benthos density immediately below the area of bridge foundation construction (fig. 4).

The lack of detectable change was probably the result of the steep channel gradient and flow regime of Joe Wright Creek, which allowed rapid flushing of the system. Although some sedimentation was detected, sampling methods may not have been sufficiently sensitive to detect changes in the macroinvertebrate community. In addition, the Surber sampler sampled only those organisms on the substrate surface and a short distance below. Areas deeper in the substrate, because they were more resistant to flushing action, could have been more adversely affected by sedimentation and the concomitant reductions in substrate permeability, intragravel velocity, and dissolved oxygen (McNeil and Ahnell 1964, Terhune 1958). Another possibility is that the sedimentation may not have been severe or persistent enough to result in biological changes. Barton (1977) and Hamilton (1961) made similar conclusions regarding the role of silt accumulation and flow.

However, in 1977, overall macroinvertebrate density and biomass values at unaffected sites were two to three times greater than at affected sites, and the discrepancy was more pronounced in slow water than fast water areas. These differences could not be assigned statistical significance because of sample variances, but based on results obtained by Needham and Usinger (1956), sufficient samples were taken to establish reliable trends.

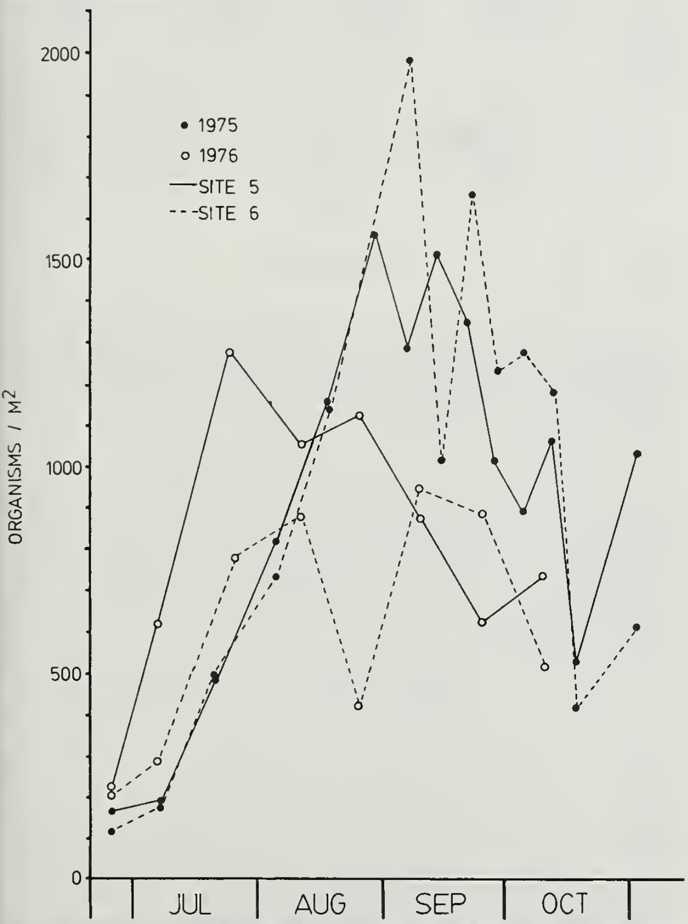

Figure 4.—Macroinvertebrate density (org/m²), fast water areas, site 5 (above construction) and site 6 (below construction), 1975-1976.

At all sites during the 3 years of study, macroinvertebrate density was consistently reduced during periods of snowmelt runoff, as exemplified by site 1 (fig. 5). Gaufin (1959) concluded that much of the density reduction could be a result of wash-out, but it may also have been affected by one or more of the following: (1) reduced sampling efficiency during high discharge periods, (2) macroinvertebrate use of the hyporheic zone as a refuge from the scouring snowmelt runoff flows, (3) macroinvertebrate diffusion across the wider wetted perimeter, or (4) inability to sample the early instars typical of most taxa during that time of year.

Throughout the study, aquatic insects comprised 90% or more of the total macroinvertebrate density except at site 7 in 1976. Ephemeroptera, Plecoptera, and Diptera were the most abundant insect orders, accounting for at least 70% of total density, but Trichoptera and Coleoptera were periodically abundant.

In 1975 and 1976, when there was no detectable effect on overall macroinvertebrate density at affected sites, the proportions of Ephemeroptera, Plecoptera, Trichoptera, and Diptera were usually similar or even higher in areas below construction. In 1977, when overall changes in macroinvertebrate density were detected, there were also changes in composition (table 4). The percentage of Ephemeroptera density increased, while Plecoptera and Trichoptera decreased at affected sites. The proportion of Diptera was considerably higher at site 2 than at site 1, but relatively similar at sites 3 and 4. Other major taxa (Oligochaeta, Turbellaria, Hydracarina, and Nematoda) were not sufficiently abundant to permit reliable interpretation of trends.

In 1977, Ephemeroptera, Oligochaeta, Hydracarina, and Nematoda were consistently higher in proportional biomass at affected sites 2 and 4. All other taxa (Plecoptera, Trichoptera, Coleoptera, Diptera, and Turbellaria) were mixed in their response to highway construction activities.

Shannon-Weaver Diversity Index values generally supported previous evidence of a construction effect on the macroinvertebrate community (table 3).

The response of individual macroinvertebrate taxa to construction activity in 1975 and 1976 was mixed. However, in 1977, some consistent changes in the density of individual taxa paralleled changes in overall density. Sixteen taxa from five orders (appendix) displayed intolerance to construction activities and tended to experience a greater percentage reduction in slow water areas than fast water areas. However, the significance of these results is limited because: (1) it is not known whether the same response would occur throughout the geographical range of the species, and (2) in some cases, species level determinations were precluded by the lack of adequate identification keys. Other taxa which displayed inconsistent responses, occurred in densities too low for accurate evaluation.

Thus, data from 1977 were indicative of changes in macroinvertebrate density and species composition, similar to findings by Cordone and Kelley (1961) and others (Einstein 1972, European Inland Fisheries Advisory Commission 1965, and Sorensen et al. 1977) who

Table 4.—Percentage composition by density of four aquatic insect orders during and after highway construction activities adjacent to Joe Wright Creek, 1977

	Study site			
	1(U)[1]	2(A)	3(U)	4(A)
Slow water areas:				
Ephemeroptera	48	68	66	75
Plecoptera	16	5	14	9
Trichoptera	4	4	7	4
Diptera	6	12	9	10
Fast water areas:				
Ephemeroptera	65	70	72	78
Plecoptera	11	10	11	4
Trichoptera	5	4	8	5
Diptera	4	6	7	9

[1]*U = unaffected site, A = affected site*

reviewed the effects of increased suspended solids and subsequent sedimentation on stream biota. The sedimentation of gravel and sand which occurred downstream from construction, altered the primarily riffle type substrate morphology to that of a pool. Such transition can have an adverse effect on stream benthos (Bjornn et al. 1974, Rabeni and Minshall 1977, Ward 1975).

Fishes

Rainbow trout (*Salmo gairdneri*), cutthroat-rainbow trout hybrids (*S. clarki* × *S. gairdneri*), and longnose suckers (*Catostomus catostomus*) were the most common fish in Joe Wright Creek. Occasionally, brown trout (*Salmo trutta*), lake trout (*Salvelinus namaycush*), and kokanee salmon (*Oncorhynchus nerka*) also were found, and presumably were escapees from Chambers Lake, which was stocked by the Colorado Division of Wildlife.

The degree of cutthroat-rainbow hybridization varied, but hybrids tended to show more of the cutthroat features. Even those specimens which appeared to be pure cutthroat trout had to be considered hybrids because of rainbow trout stocking by the Colorado Division of Wildlife.

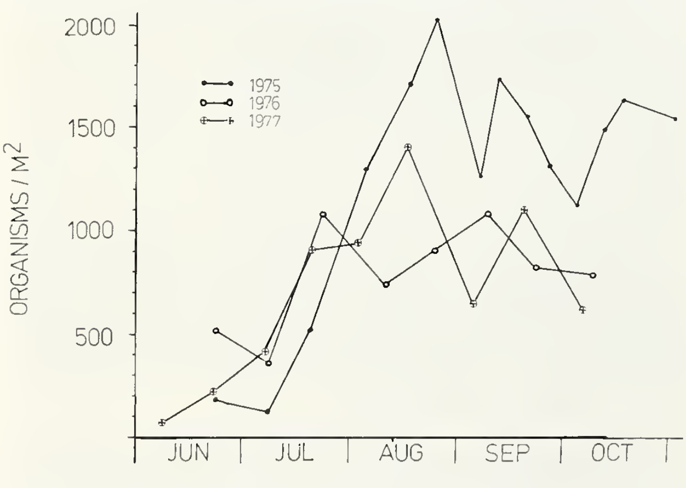

Figure 5.—Macroinvertebrate density (org/m²), fast water areas, site 1 (above construction), 1975-1977.

The average coefficient of condition (K) for rainbow trout was higher than values found for other riverine populations (table 5) (Carlander 1969). Values were higher in unaffected (2.46) than affected (1.20) stream reaches (primarily because of differences between age II fish) but the variances were extremely high, precluding statistical significance. This probably was the result of stocking hatchery-raised fish, which tend to have initially higher K factors which decrease after stocking (Carlander 1969).

The cutthroat-rainbow trout hybrids tended to have higher K values in unaffected areas (1.57) than affected areas (1.20) (primarily because of differences between age I fish), but these differences were not statistically significant (table 5). Fish from affected areas tended to have a lower K factor than those reported by Carlander (1969), but fish from unaffected areas had average to above average K values.

Table 5.—Average coefficients of condition (K) for rainbow trout (*Salmo gairdneri*) and cutthroat-rainbow hybrids (*S. clarki* x *S. gairdneri*), Joe Wright Creek, 1975-1977.

	Rainbow Trout				Hybrid Trout			
	Unaffected sites		Affected sites		Unaffected sites		Affected sites	
Age group	N	K	N	K	N	K	N	K
I	2	1.10	1	1.81	15	2.16	12	0.96
II	14	3.96	8	1.21	19	1.23	34	1.16
III	12	1.14	8	1.13	13	1.48	23	1.46
IV	2	1.30	2	1.16	3	1.08	2	0.88
V	-	-	1	1.14	-	-	-	-
Grand mean	(30)	[1]2.46	(20)	[1]1.20	(50)	[2]1.57	(71)	[2]1.20

[1]*Variances not homogeneous. Test for equality of means of two samples whose variances are assumed unequal determined that means were not significantly different at P = 0.05.*

[2]*Variances equal. A t-test for two means indicated that means were not significantly different at P = 0.05.*

Length-weight regressions of both rainbow trout and cutthroat-rainbow hybrids were evaluated by analyses of covariance. Comparison of regression lines for fish from affected sites and unaffected sites, either for any one year or the three years combined, were not significant ($P > 0.05$).

Comparison of the regressions for the two species indicated that the rainbow trout were initially heavier than the cutthroat-rainbow hybrids, but, at approximately 250 mm total length, the hybrids were heavier. Thus, the hatchery-raised rainbow trout, although initially heavier, grew at a slower rate than the resident hybrids which reproduced naturally and were subjected for a longer time to the rigors of a high mountain stream.

Back-calculated lengths and weights at annulus formation for rainbow trout did not indicate any consistent difference in growth between fish from affected and unaffected areas. Small sample sizes and the possibility

of indistinct or spurious annuli from hatchery-raised fish precluded reliable interpretation of these data.

There were no consistent differences in back-calculated growth of the hybrid trout. Scales from these fish were small, and annuli were often indistinct. Carlson and Prewitt (1974) concluded that sagittae annulus counts were consistently one unit higher than scale annulus counts for cutthroat-rainbow hybrids in Joe Wright Creek. Similar comparisons in 1975 yielded agreement between the two age counts; in 1977, there was agreement up to and including age group II, after which sagittae annulus counts were sometimes one unit higher. Laakso and Cope (1956) reported similar anomalies in aging cutthroat trout, and concluded they resulted from differential scale development prior to the first winter of fish life. Thus, young fish may overwinter with full, partial, or no scale development, which could result in underestimation of fish age in some cases.

No differences were detected between stomach contents of fish collected from unaffected sites and affected sites. Immature Ephemeroptera and terrestrial taxa were the most frequent both numerically and volumetrically during both years, for both trout species. Carlson and Prewitt (1974) also found that terrestrial invertebrates, especially Hymenoptera, constituted an important food source for rainbow trout and cutthroat-rainbow hybrids.

Saunders and Smith (1965), Elser (1968), and Whitney and Bailey (1959) detected significant reductions in fish standing crop and biomass below construction areas. However, small sample size, scale reading difficulties, and the introduction of hatchery-raised fish confounded data and precluded definitive interpretations about the effects of construction on fish in this study.

Conclusions

A general conclusion of this study is that snowmelt runoff and spates can minimize or ameliorate considerably the effect of localized, short-term construction activity on a high elevation stream. However, flushing action merely transports sediment to lower gradient stream reaches or to lentic water bodies. Moreover, longer term, sublethal changes in ecological phenomena may not have been detected by the methods of sampling and analyses used in this study. The understanding of stream ecosystem structure and function in a total watershed context is still limited (Hynes 1976). Therefore, conclusions regarding the effects of watershed manipulations on streams should be presented cautiously.

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Appendix

Macroinvertebrate taxa intolerant of highway construction, Joe Wright Creek, 1977. Numbers in parentheses are the ranges of density reduction from slow water and fast water samples between construction affected sites 2, 4 and unaffected sites 1, 3.

Ephemeroptera
- *Ameletus sparsatus* (58-97%)
- *Cinygmula* sp. (36-76%)
- *Drunella coloradensis* (31-65%)
- *Drunella doddsi* (2-77%)
- *Rhithrogena robusta* (47-79%)

Plecoptera
- *Alloperla* (s.l.) spp. (71-97%)
- *Capnia* sp. (56-69%)
- *Zapada* oregonensis (69-92%)

Coleoptera
- *Heterlimnius corpulentus* (6-88%)

Trichoptera
- *Arctopsyche grandis* (100%)
- *Glossosoma* sp. (62-91%)
- *Oligophlebodes* sp. (13-75%)
- *Rhyacophila angelita* (2-73%)

Diptera
- *Micropsectra* sp. (62-81%)
- *Palpomyia* sp. (24-92%)
- *Tipula* sp. (59-100%)

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